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THE INFLUENCE OF AN ELECTRIC FIELD ON THE THERMAL DIFFUSION COEFFICIENT FOR GASES

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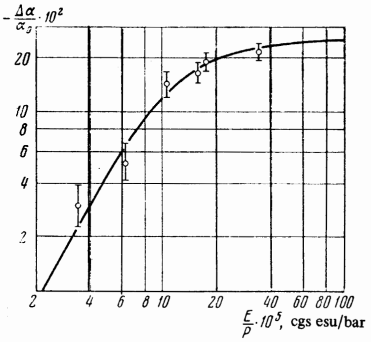
Variation of the thermal diffusion coefficient α of mixtures of gases NF_3–Ar, $C^{12}O$–$C^{13}O$ in an electric field has been observed experimentally. Experiments were carried out using apparatus of the type of a pulsed separator. The causes of the observed effect are discussed.

IT is known that the transport coefficients (viscosity and heat conductivity) of molecular gases vary in magnetic and electric fields.[1-5] Investigations have shown (cf., for example, [2,3]) that the observed effects depend on the field (H or E) and on the pressure (P) through the ratio H/P (E/P) and are described by a theory[5] which takes into account the nonspherical interaction between rotating molecules. The interaction of the magnetic moment of the molecules with the magnetic field or of the dipole moment with the electric field leads to a precession of the molecules and to an additional averaging of the scattering cross section. It is as a result of this that the transport coefficients exhibit variation.

Since the thermal diffusion constant α is, as is well known, the most sensitive coefficient with respect to a change in the parameters of the scattering potential one might expect a large variation in α in an external field compared with the other transport coefficients. However, in [6] it was shown that the relative change in α for the mixture O_2–Kr^{85} (Kr^{85} in trace amounts) in a magnetic field turned out to be $\leq 0.5\%$. As was shown in [7] this result is explained by the fact that in such a mixture when the concentration of the monatomic gas tends to zero the change in the thermal diffusion coefficient also tends to zero.

In the present work there is observed for the first time the effect of a change in the thermal diffusion coefficient in a mixture of a polar and a monatomic gas (NF_3–Ar), and also in an isotopic mixture of a polar gas $C^{12}O$–$C^{13}O$ in a constant electric field.

For measuring the thermal diffusion coefficient we have used the so-called pulsed separator which was first utilized by Clusius.[8] The pulsed separator consisted of 15 identical glass tubes of 20 mm diameter and of 200 mm height. The tubes were connected by capillaries of length ~250 mm and of diameter 1.2–1.5 mm in such a manner that the lower part of the preceding tube was connected to the upper part of the next one. The upper parts (50 mm) of all the tubes were heated to a temperature of 200 ± 0.5°C; a similar portion of the lower ends of the tubes was maintained at a temperature of 20 ± 0.5°C. In order to pump a quantity of the gas through the separator a pulsed electromagnetic pump was utilized. The magnitude of the sample being pushed through was equal to 1.5 cm^3, and the time of pumping through amounted to 100 sec. The operation of the pump was controlled by means of a programming mechanism. The tubes were placed in three rows with each row of the tubes placed between two flat electrodes the separation between which was 26 mm. The voltage was supplied to the electrodes from a high voltage stabilized rectifier. It was established experimentally that thermal diffusion equilibrium was attained in 48 hours. The volume of the sample taken amounted to 5 cm^3. The analysis was carried out by means of a mass-spectrometer MI13-05.



Two series of measurements of the thermal diffusion coefficient were carried out in an electric field with a mixture of NF_3–Ar of composition 1:1 at pressures of 28 and 54 mm Hg. In the absence of a field the following value of the thermal diffusion coefficient for this mixture was obtained: $\alpha = 0.035 \pm 0.005$. The experimental data are shown in the diagram in the form of the dependence $\Delta\alpha/\alpha_0 = f(E/P)$. As can be seen from the diagram under the conditions of the measurements that have been made the thermal diffusion coefficient diminishes in an electric field, and the quantity $\Delta\alpha/\alpha_0$ depends on the field and on the pressure through the ratio E/P.

The experimental data agree with the theoretical dependence (solid curve in the diagram) constructed taking into account the results of [7] for a mixture of a monatomic and a polar gas with molecules of the symmetric top type. Extrapolation of experimental data along the theoretical curve gives the magnitude of the effect at saturation $(\Delta\alpha/\alpha_0)_{sat}$ equal to 23%. This result is particularly interesting if we take into account the fact that the relative change in the coefficients of viscosity[9] and of heat conductivity[10] of the NF_3 gas amount to ~1%.

Similar measurements were carried out on a mixture of nonpolar gases C_6H_6–Ar. In these experiments a pressure of 40 mm Hg was maintained, while the strength of the electric field was equal to 0 and 3.08 kV/cm. The value of the thermal diffusion coefficient

U, V	P, mm Hg	E/P, V/cm·mm Hg	$\alpha \cdot 10^2$
0	35	0	0.42±0.08
250	29	3.3	0.70±0.09
500	48	4.0	0.91±0.10
500	42	4.6	1.0±0.1
1000	64	6.0	1.3±0.1
0	50	0	0.42±0.08
1000	46	8.4	1.6±0.1
2000	52	14.8	1.6±0.1
2000	42	18.3	1.6±0.1
5000	72	26.8	1.7±0.1
0	85	0	0.42±0.08
3000	30	38.5	1.6±0.1
2500	68	42.5	0.28±0.07
2500	53	54.0	0,42±0,08
10 000	58	66.5	0.85±0.10

for the mixture C_6H_6–Ar under the conditions of the experiment did not vary within experimental error.

In order to investigate the influence of the electric field on the isotopic thermal diffusion effect we chose an isotopic mixture of a polar gas $C^{12}O$–$C^{13}O$ with an initial concentration of the C^{13} isotope equal to 23.4%. Measurements were carried out in a pressure range of 29–85 mm Hg with the potential difference between the electrodes varying from 0.25 to 10 kV. The results of three series of measurements have been summarized in the table.

From the data given in the table it can be seen that the thermal diffusion coefficient increases with an increase in the ratio E/P. In the range E/P = 8.5–38.5 V/cm • mm Hg α does not vary within the limits of experimental error. For values of $E/P > 38.5$ V/cm•mm Hg the effect of the variation of α in an electric field vanishes for this mixture. The last circumstance is apparently associated with the occurrence of discharge phenomena in the separator tubes.

In our opinion an interesting circumstance is the comparatively large change in the thermal diffusion coefficient for isotopes in an electric field; $(\alpha_E/\alpha_0)_{\max} \approx 4$. At the same time such anomalous behavior of the isotopic effect apparently cannot be interpreted from the point of view of the classical Senftleben effect, since the ratio of the precession frequency for the linear CO molecules to the collision frequency amounts to $\gtrsim 10^{-2}$.

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